The Paleomagnetic Significance of Aeromagnetic Surveys of the Hawaiian Islands[1]

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ABSTRACT: Aeromagnetic surveys of the Hawaiian Islands have revealed that the primary magnetic anomalies associated with the islands are dipole anomalies caused by the intrusive rocks of the volcanic centers and rift zones. Comparisons of the direction of magnetization indicated by the dipole anomalies with results of laboratory measurements on lavas show that in many cases the lavas possess reverse polarization while the intrusive rocks are normally polarized. These results must be taken into account when interpreting the magnetic field of submerged marine volcanic features such as seamounts and when establishing periods of reversal in the earth's magnetic field.

AN AEROMAGNETIC SURVEY covering the major islands at the southern end of the Hawaiian chain has recently been completed with flight lines approximately 1 mile apart. The structural and geologic implications of this survey are discussed in detail by Malahoff and Woollard (in a forthcoming issue of *Pacific Science*), to which paper the reader is referred for examination of the actual anomaly contour maps. The dominant magnetic anomalies observed over the islands were found to be positive-negative anomaly pairs—typical dipole anomalies. Such anomalies might be expected to result from bodies with near vertical sides magnetized parallel to the present earth's field, which, in this area, has an inclination of 30–40°. From a comparison of the location of the dipole anomalies with the geologic and gravimetric data on the islands, it is apparent that they are caused by the intrusive rocks associated with the volcanic centers and major rift zones on the islands. Such a result is in agreement with laboratory determinations of susceptibility and intensity of remnant magnetization of some Hawaiian rocks made by the authors. These measurements show that the intensity of remnant magnetization is much greater in most intrusive rocks of the Hawaiian Islands than in the lavas. In both types of rocks the intensity of remnant magnetization greatly exceeded that of induced magnetization—by a factor of 1:10 in olivine-poor samples. Several model computations showed that it is possible to explain the observed aeromagnetic anomalies by assuming that the intrusive rocks were either normally or inversely polarized in a direction nearly parallel to the present earth's field. This is in agreement with measurements by Tarling (1963) of direction of remnant magnetization carried out on surface samples, primarily lavas, which also indicated directions of remnant magnetization nearly parallel to the present earth's field. Because the magnetic anomalies caused by the remnant magnetization of the intrusive rocks are dipole anomalies, it is possible to determine by inspection whether the intrusive rocks are normally or inversely polarized. This gross direction of remnant magnetization (normal or reverse) is given in Table 1, along with the results obtained by McDougall and Tarling (1963), and Doell and Cox (1963), and measurements made by the writers on surface samples of both extrusive and intrusive rocks.

The paleomagnetic and age dating results obtained by McDougall and Tarling (1963) from Hawaiian lavas have been utilized by Cox, Doell, and Dalrymple (1964) in conjunction with data from other areas to establish alternating periods of normality and reversal in the earth's magnetic field during the last four million years. The reality of these reversals, their length (if they exist), and the

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TABLE 1

SUMMARY OF GEOMAGNETIC RESULTS

FORMATION	POLARITY 1[1]	POLARITY 2[2]	POLARITY 3[3]	POLARITY 4[4]	K-AR AGE[1] M.Y.
Hawaii (historic)		N[5]	N	N	historic
Hana (East Maui)	N		N		0.4
Kula (East Maui)	N		N	N	0.86, 0.43
Honomanu (East Maui)	R[6]		N		0.86
Honolua dike rocks			R		
Honolua (West Maui)	R		R	R	1.15 ±0.02
Wailuku dike rocks			N		
Wailuku (West Maui)	R		R		1.29 ±0.03
Kahoolawe				N	
Lanai	R			N	
East Molokai	R			N	1.3–1.5
West Molokai	R			N	1.85 ±0.01
Koolau dike rocks (East Oahu)			N		
Koolau (East Oahu)	R		N and R	R	2.2–2.5
	N				2.76 ±0.02
	N				2.84 ±0.02
Waianae (West Oahu)	R			N	2.95 ±0.06
	N				3.27 ±0.04
Koloa (Kauai)	N and R		N and R	N	
Napali (Kauai)	N		N	N	4.5–5.6
Niihau				N	

[1] As determined by McDougall and Tarling (1963) primarily from extrusive material.
[2] As determined by Doell and Cox (1963).
[3] As determined by present authors on rock samples, using an astatic magnetometer.
[4] As determined by total magnetic intensity maps (intrusive rocks only).
[5] Normal polarization.
[6] Reversed polarization.

period of time over which the change from one polarity to the other took place, are extremely important in establishing a model for the main magnetic field of the earth. It is important, therefore, to explain the differences shown in Table 1 between the direction of magnetization of the bulk of the intrusive material, as revealed by the aeromagnetic survey, and that of the surface samples of the lavas. A number of possible explanations exist. The age of the bulk of the intrusive material usually is unknown and lavas of both normal and reverse polarization but different ages are sometimes found to be associated with the same volcanic center. The most obvious explanation for this difference would be that, for many centers of eruption, the bulk of the intrusive material solidified at a different time than did the lavas, whose directions of magnetization are different from the directions of magnetism of the intrusive material. At the present time it is not possible to confirm or disprove this or any other explanation for the differences. Detailed measurements of the ages and directions of remnant magnetization of the intrusive rocks of islands and determination of the types of magnetic minerals present are first necessary. It is worth pointing out, however, that differences between the direction of polarization of intrusives and extrusives which are almost certainly not due to age differences have been noted previously.

The aeromagnetic survey results also bring out several important facts which affect the interpretation of airborne or seaborne magnetic surveys over seamounts, guyots, and similar oceanic volcanic features. It has been common practice to assume that the magnetic field associated with a seamount is caused by uniform magnetization of the entire bathymetric feature.

Vacquier (1962) has proposed that such an assumption be used in determining the direction and intensity of magnetization of seamounts by constructing a model from the bathymetry and computing the direction and intensity of magnetization which gives the best fit to the observed magnetic field. However, if the primary source of the magnetic field observed over a seamount is an intrusive body associated with the seamount, such a procedure could yield quite erroneous results. Evidence for such a situation has been reported for at least one seamount in the South Atlantic (Hadley, 1964). Computations by the authors (unpublished) show that several seamounts to the west of the Hawaiian Islands have dipole anomalies associated with them which cannot be explained by a constant direction and intensity of magnetization of the entire seamount with its low dipping slopes.

A second point brought out by the present study in connection with interpretation of the magnetic field of submarine volcanic features is this: if highly magnetic intrusive rock is present, age dates or magnetic measurements made on dredged or cored flow material need not necessarily be related to the direction of remnant magnetization obtained from measurements of the magnetic field as obtained on a shipboard or airborne magnetic survey.

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